(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 233 162
A2

EUROPEAN PATENT APPLICATION

(12)

(21) Application number: 87850018.0

(22) Date of filing: 22.01.87

(51) Int. Cl.[4]: C 22 F 1/00
C 22 C 3/00, C 22 C 29/06

(30) Priority: 05.02.86 SE 8600503

(43) Date of publication of application:
19.08.87 Bulletin 87/34

(84) Designated Contracting States:
AT DE ES FR GB IT

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(54) Method of treating cemented carbide bodies regarding their compositions and structures.

(57) The present invention relates to a unique and advantageous method making possible a superior technical and economical separation of cemented carbide bodies based upon their compositions and structures.

The critical point of the method is, that after formation of a melt by melting of the binder metal including dissolved elements from the hard constituents there are so strong driving forces dependent on the grain size variables, proportions and compositions of the hard constituent phases, that melt is re-distributed between cemented carbide bodies in communicating contact. The re-distribution is determined by differences of mean grain sizes, grain size distributions, relative proportions and compositions of the hard constituent phases of the bodies.

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Description

Method of treating cemented carbide bodies regarding their compositions and structures

The cemented carbides (hard metals) are tool and wear part materials for demanding application conditions.

The present invention relates to a unique and advantageous way implying a superior technical and economical separation of cemented carbide bodies on the basis of their compositions and structures.

The elements being the main alloying elements and the most used elements in the cemented carbides are present in the earth's crust only in small percentages. The most representative metallic elements are tungsten, tantalum, niobium(columbium), cobalt and the more generally occurring element titanium. Also molybdenum, chromium, vanadium, nickel and iron are common metallic alloying elements in cemented carbide. The preparation of raw materials, possible to weigh in, for cemented carbide production in the form of powders of pure metals, metal alloys, carbides, nitrides etc demands advanced processes in many steps and with high precision.

Ore based raw materials ready for weighing in for cemented carbide production are expensive.

Collecting cemented carbide scrap and reprocessing this scrap to raw materials possible to weigh in for cemented carbide production is common today.

Chemical dissolution routes of cemented carbide scrap in connection with complete or partial separation of the metallic elements exist as processes being applied. The end products are powders of metals, metal alloys, carbides, nitrides etc possible to weigh in for cemented carbide production. Some of the chemical processes are very disadvantageous for the surrounding environment and demand rigorous protecting measures such as removal of nitrous gases. The chemical reprocessing methods are economically acceptable only if cemented carbide scrap can be acquired at costs which are generally much lower than the world-market prices of normal cemented carbide scrap. Heavily contaminated cemented carbide scrap have such low prices and are thus suitable for chemical reprocessing.

The main part of the cemented carbide scrap, which goes to re-use, is reprocessed by more direct processes than the chemical ones namely by for example the "Cold stream process" or the "Zinc process". The "Cold stream process" means mechanical disintegration of cemented carbide scrap to powder consisting of hard constituents and binder metals. The "Zinc process" is characterized by a transformation of cemented carbide scrap to powder by metallurgical means. The process is performed at temperatures generally not exceeding 1000° C. Zinc is brought to diffuse into the cemented carbide and to alloy itself with the binder metal, usually cobalt. By this the cemented carbide disintegrates into powder. Zinc is then removed in vacuum by evaporation in a furnace at high temperature in combination with precipitation in a condenser.

Thermal treatment of cemented carbide scrap in batches of conglomerated pieces at temperatures around 2000° C for generating of lumps of porous, industrially treatable but not separable, sintered together material is known.

The mentioned methods as well as other known methods of mechanical or metallurgical decomposition of cemented carbide scrap are characterized by no possibilities of separating the components being parts of cemented carbide. It has therefore been attempted before the decomposition to divide cemented carbide scrap into composition and/or structure groups by manual separation and/or by separation with methods based upon physical, chemical and/or mechanical properties of the cemented carbides.

When it relates to heavy cemented carbide bodies for such applications as high pressure synthesis, hot rolling, cold rolling, tube drawing etc the mentioned manual technique of separation works together with the measurement of for example density. A contributory reason for this is that the actual grades as well as the grades in cemented carbide bodies for rock drilling and rock cutting tools have tungsten carbide as the dominating hard constituent.

There have been attempts to find solutions on automatic separation of small cemented carbide bodies with respect to compositions and/or structures for the preparation of cheap raw materials with suitable compositions.

Separate methods tested as well as combinations of methods have been based upon the technique of letting bodies currently pass stations for automatic measurement of chemical, physical and/or mechanical data of each separate passing body. The measuring signals have been transmitted to units for the collecting and treating of the signals for controlling separating devices which have performed a dividing of the bodies into measuring data classes. Chemical data have been produced by means of for example methods based upon optical emission spectroscopy, X-ray fluorescence analysis, analysis of back-scattering of rays from radioactive sources and/or chemical analysis by means of colorimetry. Physical data produced on parts, such as density, electrical conductivity, coercivity and saturation magnetization have also been used as basis for separation. Among mechanical data hardness has been used as a base for separation.

Separation of cemented carbide scrap in classes by industrial machineries based upon magnetic and gravimetric methods has been tested and is possible to use.

The patents US 4,466,945 and US 4,470,956 are related to the utilisation of the measurement of coercivity for the separation of cemented carbide bodies having almost the same binder metal contents. Chemical composition is in the two patents proposed to be established by X-ray fluorescence determinations or by optical emission spectroscopy determinations. The production of powders is tied to the Zinc process - US 4,466,945 - or to chemical dissolution of binder metal with hydrochloric acid - US 4,470,956.

The grades, which are found in small scrapped cemented carbide bodies with weights around 100-150 g and lower, include the most common grades concerning compositions and structures. The main part of small scrapped cemented carbide bodies have been used for chipforming machining of metals and other materials. The largest and most important group is the indexable cutting inserts, whose mean weight is about 10 g.

Within the field of chipforming machining the grades have not, unlike the fields of application, been standardized. The different cemented carbide producers develop, design and manufacture their grades, cutting inserts and tools based upon experiences, estimations and ideas. Cemented carbide grades for chipforming machining are characterized by an abundance of compositions and structures. A rough, much overlapping relation exists, as the table below shows, between fields of application, on one hand, and material data, on the other hand, particularly compositions and structures. The hardness and composition values of the table can - weighed against each other - be considered as an indication of the mean grain sizes of the hard constituent phases.

Field of application ISO	Compositions % by weight			Hardness Vickers units HV
	WC	(TiTaNb)C	Co	
P10	55-70	20-35	7-10	1500-1750
P20	65-80	12-25	7.5-10.5	1450-1650
P30	70-82	7.5-20	8-11	1400-1600
P40	74-86	5-15	8.5-13	1300-1500
M10	83-88	7-10	5-7	1450-1700
M20	81-86	8-11	6-8	1350-1600
K05	92-97	0-3	3-5	1700-1950
K10	89-95	0-4	5-7	1600-1850
K20	88-94	0-4	6-8	1400-1650

The overlaps have become still more complex after the advent of coated cutting inserts. Such cutting inserts amount to about the half of all the cutting inserts being produced. The layers have a thickness of 5-10μm and consist for example of titanium carbide, titanium nitride, titanium carbonitride, hafnium carbide, hafnium nitride and/or aluminium oxide.

The abundant supply of coated cutting inserts have caused that the mentioned separation methods based upon determination of contents of chemical constituents have failed.

From the table it is evident that separation methods based upon properties which follow the binder metal contents can only be used for a very rough division.

The density of cemented carbide grades for chipforming machining is essentially within the range of 10-15 g/cm^3. Important constituents of cemented carbide have the following densities:

Tungsten carbide 15.7 g/cm^3
Tantalum carbide 14.5 g/cm^3
Cobalt 8.9 g/cm^3
Niobium carbide 7.8 g/cm^3
Titanium carbide 4.9 g/cm^3

Cemented carbide grades show considerable overlappings with respect to densities. Gravimetric methods make therefore only a rough separation possible.

A technically economically realistic, industrial separation of scrapped cemented carbide bodies requires high capacity. High capacity means, however, a reduction of the separation accuracy. Requirements on capacity and separation accuracy in a situation where the material data of the various grades are characterized by complex overlap have caused that a more or less mechanized and automatized separation of cemented carbide bodies based upon material data of various grades has not reached any appreciable spread or

importance.

The present invention shows, however, quite surprisingly that the contents of binder metal can be redistributed between cemented carbide bodies so that a superior, rational separation of compositions by means of methods described in the foregoing can be technically economically possible and attractive.

If cemented carbide is heated to the temperatures of beginning melting, a melt is formed of the binder phase forming elements - principally cobalt, nickel and/or iron, - and of elements dissolved from the hard constituent phases. Cemented carbide bodies coated with layers of for example titanium carbide, titanium nitride, titanium carbonitride, hafnium carbide, hafnium nitride and/or aluminium oxide get their layers attacked and broken down by the melt. Bridges are formed between bodies being in contact with each other. The cemented carbide bodies form systems of vessels having molten binder metal with dissolved elements as a communicating liquid.

Cemented carbide grades are characterized by the fact that they besides the binder metal phase, where cobalt, nickel and/or iron are the dominating elements, hold one or more hard constituent phases, as a rule one or two, namely hexagonal hard constituent phase, tungsten carbide, and/or cubic hard constituent phase consisting of for example titanium carbide, tantalum carbide, niobium carbide and/or vanadium carbide etc. with tungsten carbide in solid solution. The chemical composition - described by contents and compositions of phases - as well as the mean grain sizes and the grain size distributions determine the properties by which the cemented carbide grades are characterized. When cemented carbide is heated according to the present invention it is found that the mean grain sizes, grain size distributions, proportions and compositions of the hard constituent phases have a directing influence upon the melts, communicating with each other in the cemented carbide bodies. Bodies in communicating contact with each other have thus a uniting community of melt. The effect of the surprisingly strong driving forces is that bodies with coarse-grained hard constituent grains will accommodate themselves to a lower content of melt than bodies having more fine-grained hard constituents. In grades where for example titanium carbide, tantalum carbide, niobium carbide, vanadium carbide, hafnium carbide, titanium nitride and related hard constituents are present wholly or partly instead of tungsten carbide, the capacity of holding the melt is reduced when bodies of said grades occur together with bodies of grades having higher contents of tungsten carbide. The average content of binder phase forming metals, principally cobalt, nickel and/or iron, in a system of bodies in contact with each other will regulate together with the mentioned hard constituent factors the contents of melt in the bodies, respectively.

Hard constituents in the form of for example the earlier mentioned carbides or nitrides in contact with one or more elements of the iron-group metals as main element can be brought to grow in grain size by increasing the temperature level above the temperature of beginning melting and prolonging the time at said temperature level. By well-balanced cycles of temperature and time a strengthened instrument for redistribution of melt is attained. It has been found that treatments of bodies in communicating contact with each other according to the invention have to be performed at temperatures within the temperature interval 1250°C-2500°C, preferably 1350°C-2350°C and particularly 1400°C-2200°C. The time at the treatment temperature, i.e. the highest temperature, has to be within a time interval not exceeding 10 hours, preferably not exceeding 8 hours and particularly not above 5 hours. Cemented carbide bodies being furnace treated must in order to give the intended redistribution have representative amounts of the bodies making a suitable batch, completely or partly in communicating contact. Least 75 % by weight, preferably least 85 % by weight and particularly least 95 % by weight of the bodies in a batch have to be in communicating contact with each other. At rising temperature the content of formed melt as well as the vapour pressures of the elements in the melt increase. At rising temperature liquid phase is redistributed to an increasing extent via gas phase. Direct contact between the bodies is not necessary for communicating contact in treatments at temperatures within the upper range of the temperature interval. It is essential that the redistribution of melt between the cemented carbide bodies becomes as complete as possible. Therefore, more than 75 % by weight, preferably more than 80 % by weight and particularly more than 85 % by weight of the bodies being treated according to the invention, have to weigh less than 150 g, preferably less than 125 g and particularly less than 100 g.

A communicating contact is synonymous with a redistribution of melt taking place with a minimized formation of bonds between bodies. Bodies in a batch being subjected to furnace treatment according to the invention and then cooled to room temperature can, however, be more or less strongly metallurgically bonded to each other. The melt has of course solidified. It has been found that in order to make an acceptable separation into composition and structure classes possible at least 65 % by weight, preferably at least 75 % by weight and particularly at least 85 % by weight of the amount treated according to the invention has to comprise bodies which after mechanical separation treatment contain at the most 10 % by weight, preferably at the most 7.5 % by weight and particularly at the most 5 % by weight of metallurgically bonded material of different kind.

The following examples describe results from treatments of cemented carbide bodies according to the invention.

Example 1

In the production of cemented carbide buttons for rock drill bits the buttons of a grade 1 from lot A happened to be mixed with buttons of a grade 2 from a lot B. The buttons of the two different lots were identical regarding design and size. The amount of buttons from lot A was twice as large as the amount of buttons from lot B. The data of the grades of the sintered buttons were:

Grade	Composition, % by weight WC	Co	Density g/cm^3	Hardness HV
1	94	6	14.9	1400-1450
2	94	6	14.9	1525-1575

The table shows (indirectly) that the grades being equal in chemical composition had different carbide grain sizes.

The buttons were placed on graphite trays by means of vibration feeders in single layers at random orientation in relation to each other and having a direct metallic contact. Each tray contained about 10 kg of buttons having a weight of 20 g per button. A furnace was loaded with totally 450 kg of material. The batch was heated to 1425°C and maintained for one hour at said temperature. The furnace atmosphere consisted of hydrogen. After cooling of the batch the furnace was emptied. The bodies were separated from each other by a pneumatic percussion machine. It was established that 90 % by weight of the bodies had less than 4 % by weight of metallurgically bonded material from a different grade.

The bodies being separated from each other then passed an automatically working machinery provided with a weighing equipment for weighing without and within a magnetic field, counteracting the force of gravity, and having a sorting equipment controlled by a microprocessor based on weighing data. By a calibration with standard bodies the plant was brought to divide the batch into two lots. The amounts of the two lots were to each other as 2 to 1. The bigger lot has been indicated with C and the smaller one with D. Samples were taken for chemical analysis, density determination, hardness measurement and structure examination. The following results were obtained:

Lot	Composition, % by weight WC	Co	Density g/cm^3	Hardness HV
C	94.9	5.1	15.0	1475-1500
D	92.3	7.7	14.7	1500-1525

Metallurgical examinations showed that the bodies of lot C had the same carbide grain size as the bodies of lot A. Likewise, the bodies of the lots D and B showed structural agreement. A furnace treatment according to the invention had made a rational separation of the buttons of lot A from the buttons of lot B possible. The two treated lots produced by furnace treatment and separation were re-processed to cemented carbide powder by means of the zinc process.

Example 2

Two lots of cutting inserts SPUN 120308 had through mistakes in connection with stocking of not yet marked inserts been mixed to one lot. One of the lots, lot A, contained 3 times as many cutting inserts as the other lot, lot B. The inserts of the two lots were coated with layers of titanium carbide. The cemented carbide grades, which represented the material of the substrates of the cutting inserts for the two lots, were not the same. The following applies to the two grades:

Lot	Composition, % by weight			Hardness
	WC	(TiTaNb)C	Co	HV
A	85.9	8.6	5.5	1550
B	92.3	1.7	6.0	1500

The cutting inserts were placed on graphite trays by means of vibration feeders in single layers at random orientation in relation to each other and having direct metallic contact with each other. A furnace was loaded with totally 300 kg of cutting inserts. The batch was heated to 1500°C and maintained for two hours at said temperature, after which the batch cooled to room temperature. It was established that 95 % by weight of the cutting inserts had less than 3 % by weight of metallurgically bonded material from a different grade. Samples were taken out for metallographical examination and chemical analysis. The metallographic examination showed that the titanium carbide layers had been dissolved during the furnace treatment. Furthermore, the chemical analysis showed that the cutting inserts of lot A, i.e. those inserts having the higher content of the cubic hard constituent phase - (TiTaNb)C with dissolved WC - had got the cobalt content decreased to 5.1 % by weight, while the cutting inserts of lot B had got the cobalt content increased to 7.1 % by weight.

The cutting inserts being separated from each other were fed through an automatically working machinery consisting of an equipment for the measuring of the cobalt content of the cutting inserts by emission spectroscopy connected with a sorting equipment controlled by microprocessor based on analysis data. The effectiveness of the sorting equipment in function was calibrated by standard bodies. The time for the emission of radiation from the arc could be held as low as 2 seconds per cutting insert. The amount of cutting inserts originating from lot A was three times larger than the amount of cutting inserts of lot B. Final transformation to powder was performed by the zinc process.

Claims

1. Method of re-distribution of binder metal between cemented carbide bodies being a mixture of bodies separable into two or more cemented carbide grades being different from each other by the proportions, compositions, mean grain sizes and/or grain size distributions of the hard constituent phases, **characterized** in, that the bodies are heated to a highest temperature within the temperature interval, 1250°C-2500°C, and preferably within the temperature interval 1350°C-2350°C and that at least a representative amount of the bodies are entirely or partly in communicating contact with each other.

2. Method according to the claim 1, **characterized** in, that the time at the highest temperature does not exceed 10 hours and preferably does not exceed 8 hours.

3. Method according to any of the preceding claims, **characterized** in, that the communicating contact means a flow of melt between the bodies and/or as a consequence of vaporization and condensation a flow of the elements of the melt between the bodies via a gaseous phase.

4. Method according to any of the preceding claims, **characterized** in, that the bodies after treatment according to the method and after separation from each other, consist of at least 65 % by weight and preferably least 75 % by weight of bodies having at the most 10 % by weight and preferably most 7.5 % by weight of metallurgically bonded material of different kind.

5. Method according to any of the preceding claims, **characterized** in, that at least 75 % by weight and preferably at least 85 % by weight of the bodies in a batch are in communicating contact.

6. Method according to any of the preceding claims, **characterized** in, that more than 75 % by weight and preferably more than 80 % by weight of bodies being treated, are weighing less than 150 g and preferably less than 125 g.